



On February 14, 2013 a 10,000 ton meteor about 17-meters in diameter entered Earth's atmosphere over Russia traveling at 40,000 mph (18 km/s). It detonated in the air over the town of Chelyabinsk and the explosion caused major damage to the town injuring 1,000 people. The people were hurt by flying glass when the windows of over 3000 buildings blew out over an area of about 1000 km². Unlike the famous Tunguska Event of 1908 which blew down 80 million trees and was not 'discovered' for many decades afterwards, the Chelyabinsk Meteor was extensively videoed by hundreds of dashcams and cell phones as it happened.



Studies of thousands of meteor sightings by scientists can now tell us just how often asteroids of 4-meters or larger enter Earth's atmosphere. About two of these events happens each year over the entire surface area of Earth, which is 500 million km²!

Problem 1 – The surface area of Earth consists of 72% oceans and 28% land. Of the land area, only 3% is inhabited. How many years would you have to wait to hear about one of these large meteor events in the News?

Problem 2 – Fireballs are very bright meteors that streak across the sky. They are caused by pieces of meteors that can be 500 grams or more in mass. Astronomers estimate that 50,000 of these 'Bolides' can be seen every year over the entire surface area of Earth. From an inhabited spot on Earth, about how many Bolides should you be able to see in your lifetime if you paid attention to the sky if you could see any bolide entering over an area about 100 km²?

Problem 3 - The kinetic energy in Joules of a large meteor is given by $KE = \frac{1}{2}mV^2$ where m is its mass in kilograms and V is its speed in meters/sec. One ton of TNT explodes with an energy of 4.2×10^9 Joules. How many tons of TNT did the Chelyabinsk Meteor yield as it exploded if 1 ton = 1000 kg?

Problem 1 – The surface area of Earth is consists of 72% oceans and 28% land. Of the land area, only 3% is inhabited. How many years would you have to wait to hear about one of these large meteor events in the News?

Answer: The inhabited area of Earth is 3% of 28% of the total surface area or just 0.8% of Earth's total surface area. This is 1/125 of the full area. If you had one event per year, you would have to wait 125 years for the next one. If you had 2 events per year, you would have to wait half this time or about **62 years**. So, in a typical 70-year human lifetime, you will hear about one or two of these major impact events in the News!

Problem 2 – Fireballs are very bright meteors that streak across the sky. They are caused by pieces of meteors that can be 500 grams or more in mass. Astronomers estimate that 50,000 of these 'Bolides' can be seen every year over the entire surface area of Earth. From an inhabited spot on Earth, about how many Bolides should you be able to see in your lifetime if you paid attention to the sky if you could see any bolide entering over an area about 100 km²?

Answer: The 50,000 bolides arrive somewhere over Earth each year. The chance that that this area is over an inhabited region of Earth is 0.8% or 1/125. So 1/125 of the bolides arrive over an inhabited area which is $50000/125 = 400$ each year. For you to personally see the event, it has to happen within 100 km² of where you are standing. The inhabited area of Earth has an area of $1/125 \times 500$ million km² = 4 million km². Your 100 km² is only 1/40000 of this area. So you will see $400 \text{ bolides} \times 1/40000 = 1/100$ bolides each year, or will **have to wait about 100 years to see just one!** If you watched the sky every night for your entire life, you might see one of these events!

BUT, because of our world-wide news and internet coverage, you could hear about any bolide that flashed over the inhabited area of Earth or 400 bolides each year! We only hear about a few of these because most of them are too unimpressive to get the attention of the news system. After the Chelyabinsk Meteor event on February 14, 2013, there were many announcements of fireballs or bolides over Los Angeles, San Francisco and other cities as this news topic became popular for a few weeks.

Problem 3 - The kinetic energy in Joules of a large meteor is given by $KE = 1/2mV^2$ where m is its mass in kilograms and V is its speed in meters/sec. One ton of TNT explodes with an energy of 4.2×10^9 Joules. How many tons of TNT did the Chelyabinsk Meteor yield as it exploded?

Answer: The mass was 10,000 tons or $10,000 \text{ tons} \times 1000 \text{ kg/1 ton} = 10$ million kg. The speed was $18 \text{ km/s} \times 1000 \text{ m/km} = 18,000 \text{ m/s}$, so the energy was

$$KE = \frac{1}{2} (1.0 \times 10^7) \times (1.8 \times 10^4)^2 = 1.62 \times 10^{15} \text{ Joules.}$$

This is equal to $1.62 \times 10^{15} \text{ Joules} \times (1 \text{ ton}/4.2 \times 10^9 \text{ Joules}) = \mathbf{386,000 \text{ tons of TNT}}$ or about 10 times the energy of a small atom bomb. This is similar to the estimates found in the news reports of this event, and explains why it did so much damage!